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The Nature of Extreme Natural Risks in the Natural Environment

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THE NATURE OF EXTREME NATURAL RISKS IN THE NATURAL ENVIRONMENT

Professor Denis Binder*

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I. INTRODUCTION

Extreme natural hazards are well known in history. Both the Gilgamesh Epic and the Old Testament describe epic floods.¹ The historic approach of the American people has been

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to harness and tame nature.

This paper suggests a paradigm change to recognize the uncontrollable risks of extreme natural hazards. All areas of the country face extreme geological and meteorological risks. This paper discusses the historic American approach to the natural environment, the underlying nature of extreme natural hazards in Washington State, California, and the New Orleans-Mississippi River, and proposals to address these hazards. It also lays out two historic limitations on action: the Fifth Amendment and human nature.

A. *The Course of Civilization*

Civilization has spent millennia changing the natural environment. Early societies settled by bodies of water and grew into villages, towns, cities, and vast metropolises. Settlers needed water for domestic purposes, agriculture, and transportation. Rivers, lakes, and oceans remained the primary highways of commerce and transportation until a few centuries ago.

Yet these cities entered into Faustian Bargains whereby they risk flooding from upstream and the wrath of coastal storms, especially hurricanes, from the sea. Some cities, such as New Orleans, tempt fate from both directions.

Forces of nature define the natural environment; human forces redefine it. Violent natural forces created the Sierras, Cascades, and Rockies, Great Plains, and the Mojave Desert. Water carved out the Grand Canyon and Waimea Canyon. The Santa Anas, Sirocco winds and dust storms scour the land. The polar vortex and Siberian Express freeze the Frost Belt while the Pineapple Express drowns the West Coast.

Successful life forms adapt to the environment. Humans not only adapt to the environment, but they also attempt, not always successfully, more than any other species² to adapt the

of Puget Sound School of Law, in 1976 to prepare a legal memorandum on the rights of the Colville and Spokane Indians with respect to the construction of Grand Collee Dam, thereby introducing Professor Binder to infrastructure issues. His thanks to the University of Washington School of Law and the "Before the Big One" Symposium for the opportunity to bring these thoughts together.

1. See Tikva Frymer-Kensky, *What the Babylonian Flood Stories Can and Cannot Teach Us About the Genesis Flood*, 4 BIBLICAL ARCHAEOLOGY REV. 32 (1978).

2. Beavers are amazing engineers, but their expertise is limited to low head, wooden dams. They know their limits. See *How Beavers Build Dams*, PUB. BROAD. SERV. (May

environment to their will. Forces of nature such as earthquakes, floods, tsunamis, and tornadoes can be devastating and unbendable to human will. Hubristic humans believed they could control these hazards.

B. The Drive and Confidence of the American People

Settlers spanned the North American continent within 250 years, starting with conquering the forbidding wilderness of the Atlantic Seaboard. Explorers, wagon trains, railroads, and then highways spanned the continent. Settlers, first by themselves and increasingly through engineers, tried to tame or control the forces of nature. They fought nature with dams, levees and diversions. They transferred water between basins. Americans created or destroyed lakes,³ rivers, and streams.

The settlers leveled or created mountains. Seattle, Washington, a city of hills, once had more. A large regrading project a century ago flattened much of central Seattle. Denny Hill, one neighborhood affected by the project, covered sixty-two city blocks; it was leveled over eight years creating the area known as The Denny Regrade.⁴

Americans drained, dredged, and filled wetlands, which

14, 2014), <http://www.pbs.org/wnet/nature/leave-it-to-beavers-video-how-beavers-build-dams/8847/>.

3. The City of Los Angeles diverted the Owens River to Los Angeles through an aqueduct in 1913. The city continued to grow and then diverted four streams from Mono Lake to the Owens Valley Aqueduct, causing substantial environmental damage to the rapidly shrinking lake. Litigation resulted in a reassessment of the diversion. See *Nat'l Audubon Soc'y v. Superior Court*, 658 P.2d 709, 713–14 (Cal. 1983).

Destroying large bodies of water is not confined to the United States. Both the Soviet Union with the Aral Sea and Iran with Lake Urmia have essentially killed two large lakes through diversions. Lake Urmia, once the largest fresh water lake in the Middle East and twice the size of Luxembourg, shrank by 90% and split in half in 2008. Ali Mirchi et al., *Lake Urmia: How Iran's Most Famous Lake is Disappearing*, *GUARDIAN* (January 23, 2015, 7:54 AM), <https://www.theguardian.com/world/iran-blog/2015/jan/23/iran-lake-urmia-drying-up-new-research-scientists-urge-action>. See also Thomas Erdbrink, *Its Great Lake Shriveled, Iran Confronts Crisis of Water Supply*, *N.Y. TIMES* (Jan. 30, 2014), <https://www.nytimes.com/2014/01/31/world/middleeast/its-great-lake-shriveled-iran-confronts-crisis-of-water-supply.html>.

The Aral Sea, which bestrides Kazakhstan and Uzbekistan, was once the fourth largest saline lake in the world. The lake's volume shrunk to 201 km³ by 1998 from 1,060 km³ in 1960. The salinity level jumped to 100 g/l (grams per litre) from 10 g/m (grams per meter) in the same period. *The Aral Sea Crisis*, COLUM., <http://www.columbia.edu/~tmt2120/introduction.htm> (last visited May 24, 2017).

4. ROGER SALE, *SEATTLE, PAST TO PRESENT* 75–76 (1976).

were viewed as wastelands. The Supreme Court wrote in 1900:

If there is any fact which may be supposed to be known by everybody, and, therefore by courts, it is that swamps and stagnant waters are the cause of malarial and malignant fevers, and that the police power is never more legitimately exercised than in removing such nuisances.⁵

As America expanded and technology grew, the confidence of Americans to surmount any natural or human obstacle arose. People of the American nation excelled at modifying the natural environment. Indeed, the purpose of the natural environment was to serve the people. They moved water through canals, channels, tunnels, and viaducts. They harnessed the forces of nature by damming, draining, dredging,⁶ bridging, channelization, diverting and building locks⁷ on the mighty rivers of America.

Americans built great cities, spanning the continent with ribbons of asphalt, steel rails, and pipelines. Americans restrained water behind reservoirs and built coastal breakwaters to hold back the ocean. They harnessed water for domestic purposes, irrigation, hydroelectricity, and flood management. They electrified the country, built harbors, and reached to the stars with skyscrapers. They bridged the Golden Gate and built the Grand Coulee Dam.

The American people experienced a rising standard of living and quality of life. They thought public health and sanitation problems were solved. The scourge of polio was eradicated. The Greatest Generation won World War II. The nation that sent a man to the moon believed it was capable of surmounting any engineering challenge.⁸

5. *Leovy v. United States*, 177 U.S. 621, 636 (1900).

6. Many of our great ports and navigable channels were created or maintained through dredging. For example, today's Port of Los Angeles was a three foot deep bog when Juan Cabrillo, the Spanish explorer, reached the confluence of the Los Angeles River and the Pacific Ocean. The desolate tide flats were developed into one of the world's great man-made ports. *Timeline of Historic Events*, PORT OF L.A., <https://www.portoflosangeles.org/history/timeline.asp> (last visited May 25, 2017).

7. The Hiram A. Chittenden Locks (Ballard Locks) are a century old. They connect Puget Sound to Lake Washington. Their initial construction in 1912, followed by breaching a temporary dam at Montlake, led to the formal opening on July 4, 1917. The connection resulted in lowering Lake Washington by at least eight feet. *See State v. Sturtevant*, 76 Wash. 158, 161, 135 P. 1035, 1036 (Wash. 1913).

8. Professor Robin Craig of the University of Utah refers to the narrative as

II. THE REALITY OF WILD NATURE VERSUS THE HUBRIS OF HUMANITY

We now understand natural phenomenon can defy the hubris and ingenuity of humans.

A. *The "Extreme" Forces of Nature*

Every state is at risk for extreme natural hazards, which defy human control. "Extreme hazards" is a misnomer. Natural hazards can be geologic or meteorological. A definition of natural hazard is "those elements of the physical environment, harmful to man and caused by forces extraneous to him."⁹ Nature is nature. It can be mild or fierce. Extreme forces of nature may be presently uncontrollable by humans, but they are natural forces. Great cost in lives, property, and dollars demonstrate the limits of human ability to control geological and meteorological risks. Humans cannot prevent or deter the extreme, unavoidable forces of nature, such as earthquakes, hurricanes, tornadoes, tsunamis, volcanoes, ice storms, and wildfires¹⁰ nor more common risks such as flooding.

Uncontrollable forces of nature are foreseeable to experts and students of history. A tornado in Kansas, volcanic eruption in Washington, earthquake in Los Angeles, hurricane in Florida, tsunami in Alaska, or a severe ice storm in the Northeast¹¹ are highly foreseeable, even if rare as major incidents. Two commentators recognized:

"Humans as Controlling Engineers." Robin Kundis Craig, *Learning to Live with the Trickster: Narrating Climate Change and the Value of Resilience Thinking*, 33 PACE ENVTL. L. REV. 351, 354 (2016). Her narrative "emphasizes human control over nature." *Id.* at 363.

9. *What are Natural Hazards?*, ORG. OF AM. STATES, <https://www.oas.org/dsd/publications/Unit/oea54e/ch05.htm> (last visited May 8, 2017) (quoting IAN BURTON ET AL., *THE ENVIRONMENT AS HAZARD* (Oxford Univ. Press, 1978)).

10. Wildfires may be of natural causes, such as lightning, or unnatural causes.

11. The Great Ice Storm of 1998 first struck on January 5, 1998, followed by eighty hours of freezing rain and drizzle. Maine, New Hampshire, New York, Vermont in the United States and New Brunswick, Nova Scotia, Ottawa, and Quebec in Canada felt the brunt of the storm. Millions lost power, often for weeks. Forty-five died, mostly from hypothermia. Lesley-Ann Dupigny-Giroux, *Impacts And Consequences Of The Ice Storm Of 1988 For The North American North-East*, 55 WEATHER 7 (January 2000), <http://onlinelibrary.wiley.com/doi/10.1002/j.1477-8696.2000.tb04012.x/abstract>.

Though triggered by natural events such as floods and earthquakes, disasters are increasingly man-made. Some disasters (flood, drought, famine) are caused more by environmental and resource mismanagement than by too much or too little rainfall. The impact of other disasters, which are triggered by acts of nature (earthquake, volcano, hurricane) are magnified by unwise human actions.¹²

Every state is at risk for earthquakes, but the two fault lines which pose the greatest risks are on the West Coast. Other regions impacted by earthquakes are the Intermountain West; the Mississippi Valley; Missouri; and Charleston, South Carolina.¹³ The San Andreas and Cascadia Faults cover the three coastal states on the West Coast, while the New Madrid Fault is a threat in the Mississippi Valley.¹⁴ The Pacific Ring of Fire contains live, but mostly dormant, volcanoes which put the West Coast from California to Alaska and Hawaii at risk.¹⁵

Tornado Alley spans the mid-section of the United States from Texas north to Canada. Oklahoma has witnessed several major tornadoes in recent years.¹⁶ Alabama, Louisiana, and

12. ANDERS WIJCKMAN & LLOYD TIMBERLAKE, *NATURAL DISASTERS: ACTS OF GOD OR ACTS OF MAN* 6 (1984).

13. Brian Clark Howard, *Earthquake Maps Reveal Higher Risks for Much of U.S.*, NAT'L GEOGRAPHIC (July 18, 2014), <http://news.nationalgeographic.com/news/2014/07/140717-usgs-earthquake-maps-disaster-risk-science/>.

14. The New Madrid Fault set off three large earthquakes between December 1811 and February 1812. The earthquakes were so intense as to set off church bells on the East Coast. The good news is that the affected area was sparsely settled two centuries ago. John Rafferty, *New Madrid Earthquakes of 1811–12*, *ENCYCLOPEDIA BRITANNICA* (Dec. 14, 2011), <https://www.britannica.com/event/New-Madrid-earthquakes-of-1811-1812>; *Summary of 1811–1812 New Madrid Earthquakes Sequence*, U.S. GEOLOGICAL SURV., <https://earthquake.usgs.gov/earthquakes/events/1811-1812newmadrid/summary.php> (last visited May 25, 2017).

15. At least 169 active volcanoes are in the United States. Adrienne LaFrance, *The Scary State of Volcano Monitoring in the United States*, *ATLANTIC* (Feb. 28, 2017), <http://www.theatlantic.com/technology/archive/2017/02/the-scary-state-of-volcano-monitoring-in-the-united-states/518124/>.

The Kilauea Volcano on the Big Island of Hawaii is one of the most active in the world. It has been in constant eruption since 1983. The lava is flowing most of the time on the surface to the Pacific Ocean, having destroyed hundreds of homes and other structures. Mary Bagley, *Kilauea Volcano: Facts About the 30-Year Eruption*, *LIVE SCI.* (Sept. 16, 2014, 5:53 PM), <http://www.livescience.com/27622-kilauea.html>.

16. Moore, Oklahoma experienced five tornadoes in five years. The most severe was on May 20, 2013. Twenty-four died, including seven children in their school, when the tornado struck. Two hundred and twelve were injured, over 1,000 homes destroyed,

Mississippi also experience severe tornadoes.¹⁷ Tornadoes are not limited to Tornado Alley any more than seismic risks are limited to the Cascadia, New Madrid, and San Andreas Faults. For example, New England periodically experiences tornadoes. A F3 tornado¹⁸ struck central and western Massachusetts on June 1, 2011.¹⁹ Three hundred and fifty homes and businesses were destroyed and over 1,500 damaged in Springfield and surrounding communities.²⁰ The tornado's path was thirty-nine miles long.²¹ Wildfires are a major threat in the West²² and other regions domestically and internationally experience wildfire threats.²³

and much of Moore leveled. Jon Schuppe, *Moore, Oklahoma Slammed by Five Tornadoes in Five Years*, NBC NEWS (Mar. 26, 2015, 12:25 PM), <http://www.nbcnews.com/news/us-news/5-tornadoes-5-years-moore-oklahoma-dusts-again-n330561>.

The deadliest tornado in American history was the March 18, 1925 Tri-State Tornado, which plowed through thirteen counties in southwestern Missouri, southern Illinois, and southwestern Indiana. Six-hundred and ninety-five deaths were recorded dead along with 2,027 injuries. It cut a swath 219 miles long by up to one mile wide. The average speed was sixty-two miles-per-hour, but it reached up to seventy-three miles-per-hour. *Tri-State Tornado Facts and Information*, TORNADO FACTS, <http://www.tornadofacts.net/tri-state-tornado-facts.php> (last visited May 8, 2017); see also GEOFF PARTLOW, *AMERICA'S DEADLIEST TWISTER: THE TRI-STATE TORNADO OF 1925* (2014).

17. For example, 843 tornadoes were confirmed in the United States from January through August, with another 142 pending confirmation for the remainder of the year. *Tornadoes — Annual 2016*, NAT'L CTR. FOR ENVTL. INFO. (Jan. 13, 2016), <https://www.ncdc.noaa.gov/sotc/tornadoes/201613>.

18. Hurricanes are usually measured on the Fujita Scale. An F2 will have winds between 113–157 mph whereas a F5's winds will be between 261–318 mph. Rachelle Oblack, *The Enhanced Fujita Scale Explained*, THOUGHTCO, <https://www.thoughtco.com/enhanced-fujita-scale-explained-3444286> (last updated March 1, 2017).

19. THE REPUBLICAN, *PATH OF FURY: THE JUNE 1, 2011 TORNADO LEFT A 39-MILE TRAIL OF DEVASTATION THROUGH WESTERN AND CENTRAL MASSACHUSETTS 4–5* (2011).

20. *Id.*

21. *Id.*

22. Southern California suffered an epidemic of wildfires in 2003. One of the largest was the Grand Prix Fire, which consumed about 60,000 acres and merged into the Old Fire, another wildfire. See ERICH KRAUSS, *WALL OF FLAME: THE HEROIC BATTLE TO SAVE SOUTHERN CALIFORNIA* 223 (2006).

23. Australia has a history of suffering through “bushfires.” See Ken Eastwood, *Living with Bushfires*, AUSTL. GEOGRAPHIC (June 4, 2009), <http://www.australiangeographic.co.au/topics/science-environment/2009/06/living-with-bushfires>. See also *Australian Bushfires: List of the Worst Fire Disasters*, TELEGRAPH, (Feb. 8, 2009, 11:22 AM), <http://www.telegraph.co.uk/news/worldnews/australiaandthepacific/australia/4557752/Australian-bushfires-List-of-the-worst-fire-disasters.html>.

Flooding is a major risk in much of the United States, even in arid areas where sudden thunderstorms or cloud bursts can cause flash floods. The mountain valleys of Appalachia and the Rockies are subject to flash floods, often with little warning.²⁴

Parts of the country are protected by levees, as in California's Central Valley, New Orleans, and major stretches of the Mississippi River. New Orleans depends on both levees and pumps to protect itself from flooding.²⁵ If both fail, as occurred during Hurricane Katrina, the consequences are catastrophic for New Orleans and the surrounding parishes.²⁶ Just as a chain is only as strong as its weakest link, a levee system is only as strong as its weakest levee. In this respect the levee system protecting the Central Valley is believed to be weak.²⁷

Hurricanes are a constant threat along the Gulf Coast and eastern seaboard. Frequency is greater in the Southeast than the Northeast, but Hurricane Sandy, which ravaged New Jersey and New York,²⁸ is not a historical anomaly. The built-up environment on Cape Cod, Long Island, and along the littoral zone put those regions at risk for flooding like that seen in Hurricane Sandy,²⁹ which was not the first to strike the

24. For example, the Big Thompson Canyon Flash Flood of July 31, 1976 in the Colorado Rockies, below Estes Park, Colorado, killed 145 persons, and caused substantial property damage. A storm dropped a foot of rain in the canyon in a three-hour period. The wall of water reached nineteen feet high. *Colorado Remembers Big Thompson Canyon Flash Flood of 1976*, NOAA (July 30, 2001), <http://www.noaa.gov/news/stories/s688.htm>.

25. New Orleans has the world's most extensive pumping system. Brian Handwerk, *New Orleans Levees Not Built for Worst Case Events*, NAT'L GEOGRAPHIC (Sept. 2, 2005), http://news.nationalgeographic.com/news/2005/09/0902_050902_katrina_levees.html.

26. The flooding and hurricane risks to New Orleans in this paper use "New Orleans" to cover the greater New Orleans Metropolitan Area, which includes Orleans, St. Bernard, St. Charles, Jefferson, and Tammany Parishes.

27. "The US Army Corps of Engineers rated the maintenance of 120 miles of Sacramento River levees north and south of Colusa as unacceptable." Nat'l Flood Services, *Corps of Engineers Rates Sacramento River Levees Upkeep as Unacceptable*, FLOOD TOOLS (May 13, 2013), <http://floodtools.com/flooded-news-item/2013/05/13/corps-of-engineers-rates-sacramento-river-levee-upkeep-as-unacceptable>.

28. Hurricane Sandy was an extreme storm which struck New Jersey and New York. It was not though, and will not be, the first or last hurricane to lash the eastern seaboard. See Mark Fischetti, *The East Coast Is Extremely Vulnerable to Hurricane Flooding*, SCI. AM. (Oct. 2, 2015), <https://www.scientificamerican.com/article/the-east-coast-is-extremely-vulnerable-to-hurricane-flooding/>.

Northeast.

The Category 3 New England Hurricane of 1938 hit Long Island and Connecticut with a storm surge of ten to twelve feet, sustained winds of 121 mph, and gusts up to 183 mph.³⁰ During another Category 3 hurricane on August 31, 1954, the storm surge flood waters reached depths from eight to ten feet in downtown Providence, Rhode Island. The storm caused sixty deaths and \$461 million in damages.³¹ Hurricane Agnes on June 22–25, 1972 dropped between fourteen to nineteen inches of rain in the northeastern United States.³²

B. Although Foreseeable, Extreme Forces of Nature Cannot Often Be Predicted with Sufficient Specificity to Avoid Impacts

Normal weather conditions, such as droughts, heat waves, lightning, fog, frost, blizzards, and wind storms are common in many areas.³³ They often present great dangers, but residents have learned to live and cope with these risks;³⁴ these events often provide advance warnings of their onset that residents should be familiar with.

Extreme natural hazards are different. Many extreme hazards can be identified, but the identification of risks is but a preliminary step in controlling the risk, which is still often outside human capability. For example, hydrologists can map floodplains and geologists can identify seismic zones, but they cannot necessarily predict the timing, severity, and locale of impact. Thus, a general recognition of a potential extreme hazard does not necessarily allow for specific predictions. The timing of an earthquake, its location, duration, velocity, magnitude, point of impact, and direction are still unforeseeable. Tornadoes can often be tracked with warnings

29. Both Long Island and Cape Cod stick out into the Atlantic. Storms that might otherwise skirt the coast may strike them head-on.

30. *Hurricanes in History*, NOAA, <http://www.nhc.noaa.gov/outreach/history> (last visited May 8, 2017).

31. *Id.*

32. *Id.*

33. For example, Southern California is subject to drought, flooding, landslides, brush fires, wildfires, mudslides, and Santa Ana winds.

34. Prosser and Keeton posit “a defendant will be required to anticipate the usual weather of the vicinity, including all ordinary forces of nature.” W. PAGE KEETON ET AL., PROSSER AND KEETON ON TORTS § 44 at 304 (5th Ed. 1984).

available to seek shelter, but the locus of a tornado touchdown is unpredictable.³⁵

Similarly, even if the timing and course of hurricanes are generally foreseeable, the path of destruction is not. Where and when they make landfall is uncertain. Two prime examples are Hurricanes Rita and Ike. Both hurricanes had the potential to rival Katrina with their impacts. They inflicted substantial damage to coastal areas.³⁶ Rita mostly missed Texas, but struck New Orleans, re-flooding part of the city because the failed levees had not been completely restored.³⁷

Hurricane Katrina in 2005 reminded Texas residents of hurricane dangers. Hurricane Rita headed for the Texas-Louisiana coast three weeks after Hurricane Katrina.³⁸ The warnings were ominous. A mass evacuation heeded the warnings.³⁹ Traffic stalled on I-45, as one would encounter in a terrible rush hour.⁴⁰ Yet, the hurricane inflicted most of its damage on Louisiana. Hurricane Ike struck Galveston on September 13, 2008, flooding much of Galveston, engendering insured losses of \$12 billion,⁴¹ but leaving much of Texas relatively unscathed. Winds reached up to 110 mph with eighteen inches of rain. The storm surge was up to twenty feet.⁴² The hurricane was devastating, but its potential

35. A semi-facetious observation living in the Midwest is that the tornado will find the low-lying trailer park.

36. Hurricane Rita was estimated to have caused \$12 billion in damages. Jon Erdman, *Hurricane Rita Should Never Be Forgotten*, WEATHER CHANNEL (Sept. 22, 2015, 12:00 AM), <https://weather.com/storms/hurricane/news/hurricane-rita-forgotten-louisiana-texas-sep2005>.

37. Hurricane Rita breached the levees along Lake Pontchartrain and had a storm surge of fifteen feet along the Louisiana coast. *2005- Hurricane Rita*, HURRICANES: SCI. AND SOC'Y, <http://www.hurricanescience.org/history/storms/2000s/rita/> (last visited May 25, 2017).

38. Carol Christian, *8 Years Ago, Seemingly All of Houston Evacuated Ahead of Hurricane Rita*, HOUS. CHRON. (Sept. 24, 2013, 2:53 PM), <http://www.chron.com/news/houston-texas/houston/article/8-years-ago-seemingly-all-of-Houston-evacuated-4839142.php>.

39. *Id.*

40. *Id.* One of the lessons from Rita is that the authorities should open exit lanes on both sides of a freeway to expedite the evacuation.

41. *Hurricane Ike Claims Total Nearly \$12B in Texas*, INS. J. (June 29, 2010), <http://www.insurancejournal.com/news/southcentral/2010/01/29/106989.htm>.

42. Dennis Mersereau, *Five Years Later, Hurricane Ike Still Remembered Deep in the Hearts of Texans*, WASH. POST (Sept. 13, 2013), <https://www.washingtonpost.com/news/capital-weather-gang/wp/2013/09/13/five-years-later-hurricane-ike-still-remembered-deep-in-the-heart-of->

damages could have been much worse had it directly struck Dallas or Houston.

III. THE LIMITS OF HUMANS

Natural risks persist despite the greatest efforts of engineers. Try as they might, humans often lack the capacity to control extreme forces of nature, such as earthquakes, hurricanes, tornadoes, and volcanoes. Their actions may even worsen the effects of natural hazards.

The reality is that every major disaster, even of seemingly natural origin, will undoubtedly involve human fault of some sort; a combination of poor decisions and acts of negligence will often coalesce to magnify impact and damages.⁴³ It could be a judgment call, but quite often negligence lies in planning, design, construction, operations, maintenance or inspection. Deferred maintenance may especially be a problem with older facilities and systems.

The famous architect Ian McHarg taught us to design with nature to minimize risks, to build with, as opposed to, nature, and thereby minimize potential environmental problems and natural hazards.⁴⁴ Unfortunately, his advice has often been ignored.⁴⁵ For example, humans filled in wetlands and paved the upriver areas, increasing the risks downstream.⁴⁶ Inland wetlands can serve as a giant sponge. Draining, dredging, or filling them, paving the land, and building upstream, increases downstream flooding risks by increasing the water flow.⁴⁷ Pervious layers of soil are replaced with impervious layers of asphalt, cement, roofing, and tile.

texas/?utm_term=.460cbaad03cd.

43. Seemingly after every major disaster in the United States, an "I told you so" memo, report, or email emerges, highlighting the flaws in the design and predicting the ultimate failure. Human fault can include negligence, intentional wrongs, such as terrorism, or failure to plan for the accident. Negligence can be involved in the design, construction, maintenance, operations, or inspections of a facility. See Denis Binder, *Act of God? Or Act of Man?: A Reappraisal of the Act of God Defense in Tort Law*, 15 REV. LITIG. 1, 31–32 (1996).

44. See generally IAN L. MCHARG, *DESIGN WITH NATURE* (1969).

45. Architects and engineers make recommendations to the client, but the client decides on the final design.

46. See e.g., *Harris Cty. Flood Control Dist. v. Kerr*, 499 S.W.3d 793 (Tex. 2016) (finding no liability because of sovereign immunity).

47. See Denis Binder, *Taking Versus Reasonable Regulation: A Reappraisal in Light of Regional Planning and Wetlands*, 25 U. FLA. L. REV. 1, 18–19 (1972).

Great challenges exist in fighting the forces of nature. Meteorologists can track the course of a hurricane, but cannot predict exactly where and when it will strike land. Science can map the major fault lines, but cannot predict when and where “The Big One” will occur.⁴⁸ Furthermore, the ferocity of the natural hazards often cannot be tempered by engineering and design measures. Facilities and structures have design limits,⁴⁹ which may be inadequate against extreme natural risks.⁵⁰

Try as they might, humans cannot tame nature. They may temper the rivers, but they cannot prevent flooding. Rivers exceed flood levels even when dammed and channeled. Saturated soils and heavy precipitation can exceed the storage capacity of the ground and reservoirs. Little protection can also be offered to those living on hillsides and mountains against large runoffs.⁵¹

Humans remain at risk of geological and meteorological forces. Most rivers, streams, creeks, and dry washes do not flood out continually. The levees, dams, and diversions provide a large, but not absolute, margin of safety for the “normal” hazards of nature.⁵² Congress recognized the impossibility of preventing all flooding when it expressly retained sovereign immunity for water control projects, which include a flood control purpose.⁵³

Human activity can reduce natural risks, but also enhance

48. The Big One is defined as an earthquake of magnitude 8.0 or larger. David K. Lynch, *The Big One*, SANANDREASFALT.ORG, <http://www.sanandreasfault.org/BigOne.html> (last visited May 29, 2017).

49. For a discussion of design limits, see *infra* notes 157–72 and accompanying text.

50. See Michael D. Dettinger & B. Lynn Ingram, *Megastorms Could Drown Massive Portions of California*, SCI. AM. (Jan. 2013), <https://www.scientificamerican.com/article/megastorms-could-down-massive-portions-of-california/>. See also *infra* notes 148–57 and accompanying text.

51. For example, eighteen inches of rain fell on Mount Rainier in thirty-six hours on November 6–7, 2006. *November 2006 Flood*, NAT’L PARK SERV., <https://www.nps.gov/mora/learn/news/november-2006-flooding.htm> (last visited May 9, 2017).

52. For example, the heavy precipitation in California during the winter of 2017 has resulted in floods. See Jonathan Lloyd, *Aerial Photos of California’s Winter 2017 Floods, Storm Damage*, NBC LOS ANGELES (Mar. 7, 2017), <http://www.nbclausangeles.com/multimedia/Aerial-Photos-Images-Flood-Flooding-California-Winter-Storms-414728243.html>.

53. “No liability of any kind shall attach to or rest upon the United States for any damage from or by floods or flood waters at any place . . .” 33 U.S.C. § 702(c) (2012).

the risks and impacts of natural hazards, such as wildfires, especially when trees have been weakened by drought. The urban interface where homes invade the forest changes the dynamics of firefighting. Fire fighters must deploy resources to prevent, if possible, damage to residences rather than to directly fighting the fire. Residents with flammable roofs or dry foliage abutting the structure are courting a disaster with wildfires.⁵⁴

A. *Washington State: Natural Beauty and Natural Hazards*

Those of us who live in, or have resided in, Puget Sound and the Pacific Northwest are well familiar with the area's natural beauty and recreational opportunities. We also understand that the mountains, hills, rivers, and the Sound present geological risks. A look at natural disasters and risks in Washington State illustrates the legal risks of natural hazards. Seattle lies on the Pacific Rim of Fire, subject to the Cascadia Fault⁵⁵ and the dormant, but active, volcanoes surrounding the Puget Sound in the Cascade Mountain Range.⁵⁶ The 1980 eruption of Mount St. Helens is a reminder of the risks.⁵⁷

The inability of experts to make accurate predictions presented itself with the Mount St. Helens eruption. Experts quickly recognized the emerging volcanic risk as its magma bulge grew and minor earthquakes occurred, often a precursor of an eruption. Yet, problems arose in determining how to issue closures and warnings of the imminent threat of an eruption. Washington State promulgated a safety zone around Mount St. Helens prior to the eruption. The Governor relied

54. Andrew Michler, *6 Tips to Protect Your Home from Wildfires*, INHABITAT (July 23, 2013), <http://inhabitat.com/6-tips-to-protect-your-home-from-wildfires/>.

55. See Kathryn Schulz, *The Really Big One*, NEW YORKER, July 20, 2015, at 52 (depicting an apocalyptic worst case analysis of the substantial potential losses from a major earthquake and tsunami on the Cascadia Fault).

56. These include Mount Adams, Mount Baker, and Mount Rainier, and Glacier Peak.

57. Mount St. Helens' major eruption was on May 18, 1980. Fifty-seven died or remained missing after the eruption. The cloud reached 80,000 feet high in less than fifteen minutes. The streetlights turned on 250 miles away in Spokane, Washington because of complete darkness. The landslide area covered twenty-three square miles. 1,314 feet were removed from the mountain's summit. Steve Brantley & Bobbie Myers, *Mount St. Helens – From the 1980 Eruption to 2000*, U.S. GEOLOGICAL SURV., <https://pubs.usgs.gov/fs/2000/fs036-00/> (last modified Mar. 1, 2005).

upon the experts in adopting the restricted zones recommended by the United States Forest Service.⁵⁸ Red zones and blue zones were created.⁵⁹ The inner red zone was essentially off limits to everyone.⁶⁰ The outer blue zone allowed limited access through a permit system.⁶¹

The Washington Department of Emergency Services later recognized that the initial zones did not reflect the changing dynamics of the volcano. They prepared proposed revisions to the zones. However, the volcano erupted on May 18, 1980 without warning, before the Governor could act upon the proposed revisions.⁶² Sixty people, mostly beyond the red zone, were killed or missing in the eruption.

The eruption exceeded the red zone on one side of the mountain, but left unscathed some of the restrictive areas on the opposite side. Fourteen of the victims filed suit, alleging negligent drawing of the restrictive zones. Conversely, unscathed merchants on the other side of the mountain sued because their community was not removed from the restricted zone prior to the eruption.⁶³ They sought their business losses from the restrictions. In other words, the zones were over-inclusive on one side and under-inclusive on the other, as the volcano over erupted on one side and under-erupted on the other. The actual eruption was ten to fifteen times greater than the previous largest known eruption of Mount St. Helens, and fifteen times larger than an expert's worst prediction.⁶⁴ None of the experts accurately predicted the eruption.⁶⁵

The cases were filed in state court alleging a cause of action under Washington's Tort Claims Act.⁶⁶ The state won both cases.⁶⁷ The establishment of a restricted zone of entry around Mount St. Helens was viewed as essential to the preservation and maintenance of life, health, property, and the public peace.

58. *Karr v. State*, 53 Wash. App. 1, 4, 765 P.2d 316, 318 (Wash. Ct. App. 1988).

59. *Id.*

60. *Id.*

61. *Id.*

62. *Id.* at 319–20.

63. *Cougar Bus. Owners Ass'n. v. State*, 97 Wash. 2d 466, 647 P.2d 481 (Wash. 1982), *cert. denied*, 459 U.S. 971 (1982).

64. *Karr*, 765 P.2d at 319.

65. *Cougar Bus. Owners Ass'n.*, 647 P.2d at 483.

66. *Id.* at 484; *Karr*, 765 P.2d at 319; *See also* WASH. REV. CODE § 4.92 (2016).

67. *Cougar Bus. Owners Ass'n.*, 647 P.2d at 489; *Karr*, 765 P.2d at 321.

The Governor made a considered policy decision in closing areas around the mountain relying upon expert advice.⁶⁸ The decision to establish a safety zone “requires the exercise of basic policy evaluation, judgment and expertise,”⁶⁹ and while hindsight for lawyers is the best test of foreseeability, experts and emergency managers must make the best judgment they can based on the state and availability of scientific knowledge at the time.

The Mount St. Helens litigation is an example of the best experts being unable to fully predict or control natural hazards, such as volcanic eruptions. The authorities and experts made the best decisions they could under the circumstances and in light of the known science.

Mount Rainier may be a dormant volcano, but the prognosis is grim should it awaken. The damages would greatly exceed those of Mount St. Helens. The potential mudflows have been mapped, with an estimated 100,000 persons living in homes built on debris washed down the mountain by catastrophic debris flows.⁷⁰

Washington State’s second extreme weather experience is the flooding of the Paradise Visitors Center and the area around Mount Rainier during the November 2006 Flood. Eighteen inches of rain fell on the mountain in thirty-six hours on November 6–7, 2006,⁷¹ unleashing torrents of water down the mountain’s slopes. Campgrounds, roads, trails, and utilities were washed out. Rainier National Park was closed for six months to repair the damages.⁷² Even the great dams on the Columbia River and its tributaries cannot prevent flooding in extreme precipitation. For example, the Columbia River rose above flood stage in May 2011.⁷³

68. *Karr*, 765 P.2d at 319.

69. *Cougar Bus. Owners Ass’n.*, 647 P.2d at 484.

70. Jon Krakauer, *Geologists Worry About Danger of Living “Under the Volcano”*, SMITHSONIAN MAG., July 1996, at 33–34.

71. Press Release, National Park Service, Mount Rainier National Park, November 2006 Flood, <https://www.nps.gov/mora/learn/news/november-2006-flooding.htm> (last visited May 5, 2017).

72. MOUNT RAINIER NATIONAL PARK FLOOD OBSERVER, NOVEMBER 2006 FLOOD MAKES HISTORY (2007).

73. Mark Bowder, *Columbia River Rises Above Flood Stage in Vancouver: Limited Flooding Expected; Expect More Bridge Lifts* (May 27, 2011), <http://www.columbian.com/news/2011/may/28/columbia-river-rises-above-flood-stage-vancouver/>. See also Seattle Times Staff, *Forecast: Worst of Columbia River Flooding*

A third experience is the Oso Landslide that buried Oso, Washington on March 22, 2014, killing forty-three residents.⁷⁴ The landslide was on a known dangerous slide area, but the County failed to warn the residents of the area of this risk,⁷⁵ which remains subject to landslide risks.⁷⁶ In litigation, a legal argument was made that the state failed to warn the citizens that they were at risk from the landslide. The Washington Supreme Court earlier held that the state had a duty to disclose avalanche dangers,⁷⁷ since these avalanche and landslide risks are often known and mapped. The potential danger zone is highly predictable based on prior slides and geologic studies, unlike volcanic eruption zones.⁷⁸ The state settled the Oso Landslide case for \$50 million, and a private defendant settled for \$10 million.⁷⁹

Liability was reached in the Oso Landslide because the risks were known to the state, the residents could have been warned, and the disaster avoided.⁸⁰ The volcanic eruption of Mount St. Helens was different. There, only general

Over, SEATTLE TIMES (June 25, 2011 3:47 PM), <http://www.seattletimes.com/seattle-news/forecast-worst-of-columbia-river-flooding-over-1/>.

74. Jessica Robertson, *One Year Later—The Oso Landslide in Washington*, U.S. GEOLOGICAL SURVEY (Mar. 16, 2016, 12:55 PM), https://www2.usgs.gov/blogs/features/usgs_top_story/one-year-later-the-oso-landslide-in-washington/.

75. See Jim Brunner et al., *County Mudslide Warnings Failed to Reach Hill's Residents*, SEATTLE TIMES (Apr. 26, 2004), http://old.seattletimes.com/html/localnews/2023468682_mudslidenotificationxml.html. See also David Montgomery, *Guest: Map the Runoff Risk for Landslides Like Oso*, SEATTLE TIMES (Apr. 14, 2014), http://old.seattletimes.com/html/opinion/2023376128_davidmontgomeryopedosolandslidexxml.html; Warren Cornwall, *Causes of Deadly Washington Mudslide Revealed in Scientific Report*, NAT'L GEOGRAPHIC (July 24, 2014), <http://news.nationalgeographic.com/news/2014/07/140722-oso-washington-mudslide-science-logging/>.

76. Sean R. LaHusen, et al., *Surface Roughness Dating of Long-runout Landslides Near Oso, Washington (USA), Reveals Persistent Postglacial Hillslope Instability*, 44 GEOLOGY 111, 113 (2015), <http://geology.gsapubs.org/content/early/2015/12/22/G37267.1.full.pdf>.

77. *Brown v. MacPherson's*, 545 P.2d 13, 19 (Wash. 1975).

78. *Avalanche Control*, WASH. ST. DEPT. TRANSP., <http://www.wsdot.wa.gov/maintenance/avalanche> (last visited June 16, 2017).

79. Mike Carter, *'This must never happen again': Oso landslide survivors reach settlements totaling \$60 million*, SEATTLE TIMES (Oct. 10, 2016), <http://www.seattletimes.com/seattle-news/timber-company-reaches-10m-settlement-in-oso-landslide-suit/>.

80. *Id.*

foreseeability existed; the state made the best judgment available in light of the advice of the experts, dealing with an eruption which turned out to exceed all predictions.⁸¹

B. The Mississippi River and New Orleans: A Sisyphean Exercise in Flood Control

The Mighty Mississippi is a prime example of the best engineering and levees restraining what might be called “normal” floods but unsuccessful in controlling extreme flooding. New Orleans was settled in 1718 by the French; occupants from then on have battled the elements.

The hubris of Americans was exemplified by the Chief of Engineers of the United States Army Corps of Engineers in 1926. He wrote, after surveying the massive levee system lining the Mississippi, the Mighty Mississippi could be controlled to prevent the “destructive effects of floods.”⁸²

Mark Twain, a former Mississippi River pilot, held the opposite view in the nineteenth century:

One who knows the Mississippi will promptly aver—not aloud, but to himself—that 10,000 river commissions, with the mines of the world at their back, cannot tame that lawless stream, cannot curb it or confine it, cannot say to it, Go here or Go there, and make it obey; cannot save a shore which it has sentenced.⁸³

The Mighty Mississippi quickly validated Mark Twain with the historic Great Flood of 1927, which inundated 16,570,627 acres over 170 counties in seven states.⁸⁴ Over 162,000 homes were flooded and 41,487 buildings destroyed.⁸⁵ Fatalities range between 250 and 500 persons.⁸⁶

The 1927 flood was not an anomaly. The Great Flood of 1993

81. Veronica Jennings, *Mt. St. Helens Dispute Erupts Into Lawsuit*, WASH. POST (July 25, 1981), <https://www.washingtonpost.com/archive/realestate/1981/07/25/mt-st-helens-dispute-erupts-into-lawsuit/a56d7cde-7edf-4951-9a84-fa89dd76716a/>.

82. Pete Daniel, *DEEP'N AS IT COMES: THE 1927 MISSISSIPPI FLOOD* 6 (1976) (quoting the annual report).

83. Mark Twain, *LIFE ON THE MISSISSIPPI* 172–73 (Signet Classics ed., 1963).

84. Daniel, *supra* note 82 at 8. See also John M. Barry, *Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America* (1997).

85. Daniel, *supra* note 82 at 8.

86. *Id.*

covered eight months and impacted nine states.⁸⁷ An estimated 54,000 persons were evacuated and over 50,000 homes damaged or destroyed.⁸⁸ The high-water mark of the Mississippi at St. Louis reached a record forty-nine to fifty-eight feet.⁸⁹ The excessive precipitation caused the largest flood ever measured in St. Louis.⁹⁰ Five towns were completely inundated with Hannibal, Louisiana, and Clarksville, Missouri under water for 153 consecutive days.⁹¹ Over twenty million acres of land were inundated in the nine states.⁹² The six-month flood period was caused by a previous wet fall with saturated soils, normal to above normal snow accumulation in winter, rapid spring snowmelt, and heavy thunder storms.⁹³

The flooding risks on the Mississippi differ between the Upper Mississippi and the Lower Mississippi because the Lower Mississippi is wider and deeper with a greater carrying capacity than the upper Mississippi.⁹⁴ The Army Corps of Engineers has further reduced the flood risks to the New Orleans area from upstream through diversion facilities. Thus, the flood waters tend to have a lesser impact on the Louisiana segments of the River. The bypass facilities are first above New Orleans through the Morganza Spillway into the Atchafalaya and thence into the Gulf, and second through the Bonnet Carre into Lake Pontchartrain. Severe flood waters are thereby diverted away from New Orleans to other areas in Louisiana.⁹⁵

87. NAT'L OCEANIC AND ATMOSPHERIC ADMIN., THE GREAT FLOOD OF 1993 x (1994).

88. *Id.* at xvii.

89. *Id.* at 1-1. The Mississippi River was expected to crest at 39.4 feet on the St. Louis riverfront in April 2013, roughly nine feet above flood stage. *Mississippi River to Crest Above Flood Stage, Locks to Close*, CBS ST. LOUIS (Apr. 19, 2013), <http://stlouis.cbslocal.com/2013/04/19/mississippi-river-to-crest-above-flood-stage-locks-to-close/>.

90. U.S. GOV'T ACCOUNTABILITY OFF., GAO/RCED-95-125, MIDWEST FLOOD: INFORMATION ON THE PERFORMANCE, EFFECTS, AND CONTROL OF LEVEES 2 (1995).

91. NAT'L OCEANIC AND ATMOSPHERIC ADMIN., *supra* note 81, at 1-3.

92. *Id.* at 1-4.

93. *Id.* at 1-2.

94. Suzanne Fournier, spokeswoman for the Army Corps of Engineers, said "South of St. Louis, the Mississippi is much wider and deeper, minimizing the impact of the flooding upstream." William Branigin, *St. Louis Levees Are Expected to Hold Mississippi*, WASH. POST (June 21, 2008), <http://www.washingtonpost.com/wp-dyn/content/story/2008/06/20/ST2008062002918.html>.

95. JOHN MCPHEE, THE CONTROL OF NATURE 6, 9 (1989); Mark Guarino, *Morganza Spillway: Flooding Farmland to Save New Orleans*, CHRISTIAN SCIENCE MONITOR

The un-channeled Mississippi River in its natural state is an example of natural forces constantly changing the natural environment. The potential always exists for the river to overwhelm human defenses. The Mississippi River, pursuant to its wandering history, wants to bypass Baton Rouge, New Orleans and the industrial complex along the current banks of the Mississippi, and follow the Atchafalaya to the Gulf, west of New Orleans.⁹⁶ The Army Corps of Engineers manages a river control system, which funnels 70 percent of the Mississippi through its current course to New Orleans and 30 percent to the Atchafalaya.⁹⁷

The main flooding risk in New Orleans comes from hurricanes blowing up the Mississippi River and Lake Pontchartrain,⁹⁸ and overflowing the levees, as occurred with Hurricane Katrina. New Orleans has been struck nine times before Katrina, including the major hurricanes of Betsy in 1965⁹⁹ and Camille in 1969.¹⁰⁰ It is highly foreseeable that New Orleans will be struck again, many times. A prescient expert's worst case scenario was that New Orleans could become a twenty foot' deep lake. The storm surge would enter Lake Pontchartrain, overflow the levees, and pour into the city. The

(May 15, 2011), <http://www.csmonitor.com/USA/2011/0515/Morganza-spillway-Flooding-framland-to-save-New-Orleans>.

96. Alexis C. Madrigal, *What We've Done to the Mississippi River: An Explainer*, THE ATLANTIC (May 19, 2011), <https://www.theatlantic.com/technology/archive/2011/05/what-weve-done-to-the-mississippi-river-an-explainer/239058/>.

97. MCPHEE, *supra* 95 at 10–11.

98. Lake Pontchartrain is a 640-square mile tidal basin coming off the Gulf of Mexico. It is connected to the Gulf through Lake Borgne and the Mississippi Sound.

99. Hurricane Betsy struck Grand Isle, Louisiana on September 9, 1965 and moved up the Mississippi River. The Mississippi level rose ten feet by New Orleans. It breached the levees on the Industrial Canal in New Orleans. About 164,000 homes were flooded. Seventy-six deaths resulted from the hurricane and an estimated \$1.42 billion in damages resulted. As a result of Hurricane Betsy, the Army Corps of Engineers designed the Hurricane Protection Program with the intent of protecting New Orleans from a Category 3 hurricane. 1965 - *Hurricane Betsy*, HURRICANES: SCIENCE AND SOCIETY, <http://www.hurricanesociety.org/history/storms/1960s/betsy/> (last visited May 29, 2017).

100. Hurricane Camille struck the Gulf Coast on August 17, 1969. It flooded 860,000 acres in Louisiana and "forced the Mississippi river to flow backwards from its mouth in Venice, LA to a point north of New Orleans" 1969 - *Hurricane Camille*, HURRICANES: SCIENCE AND SOCIETY, <http://www.hurricanesociety.org/history/storms/1960s/camille/>.

surviving levees would trap the flood water within the city.¹⁰¹ Much of that scenario transpired with Hurricane Katrina.

The weakened levees failed during Katrina. Over 8 percent of New Orleans and much of the surrounding area was flooded.¹⁰² Several postmortem studies were undertaken to determine the causes of the disaster. A Corps of Engineers Study found “[t]he storm exceeded design criteria, but the performance was less than the design intent.”¹⁰³ Fifty levees failed, forty-six of which were caused by overtopping¹⁰⁴ and erosion, and four by foundation failures.¹⁰⁵

The overtopping of the Inner Harbor Navigation Canal (IHNC) exceeded design levels. The structure had shrunk by two feet over thirty-five years, illustrating the shrinking nature of the ground in the New Orleans area.¹⁰⁶ The flooding was compounded because many of the pumping stations were not designed with the capacity to handle large storms.¹⁰⁷

Earlier hurricanes exposed the vulnerability of New Orleans.¹⁰⁸ A Category 4 hurricane struck New Orleans in 1915. A fifteen to twenty foot storm surge swept up the Mississippi, overwhelming the levees. Lake Pontchartrain rose six feet over sea level, overtopping its embankments.¹⁰⁹

A Category 3 hurricane in 1947 also overwhelmed defenses

101. Francis F. Marcus, *Storm Adds Reality to New Orleans Drill*, N.Y. TIMES, May 14, 1995, at 18.

102. Ann Zimmerman, *Hurricane Katrina: Facts, Damage & Aftermath*, LIVE SCIENCE (Aug. 27, 2015), <https://www.livescience.com/22522-hurricane-katrina-facts.html>.

103. U.S. ARMY CORPS OF ENG’RS, PERFORMANCE EVALUATION OF NEW ORLEANS AND THE SOUTHERN LOUISIANA HURRICANE PROTECTION SYSTEM: DRAFT FINAL REPORT OF THE INTERAGENCY PERFORMANCE EVALUATION TASK FORCE at I-3 (2006).

104. Overtopping is the phenomenon whereby water, usually flood water, will flow over the top of the dam, levee, or other embankment. If, for example, the dam is fifteen feet high, and the river level reaches sixteen feet, it will overtop the dam. The design limits of the dam would have been exceeded.

105. U.S. ARMY CORPS OF ENG’RS, *supra* note 103 at I-7.

106. *Id.* at I-4.

107. *Id.* at I-5–I-6.

108. For a history of New Orleans hurricanes, see Stephen A. Nelson, *Why New Orleans is Vulnerable to Hurricanes: Geologic and Historical Factors*, TIDE-1220 TULANE UNIVERSITY (Dec. 10, 2012), http://www.tulane.edu/~sanelson/New_Orleans_and_Hurricanes/New_Orleans_Vulnerability.htm.

109. Patricia Grossi & Robert Muir-Wood, *Flood Risk in New Orleans: Implications for Future Management and Insurability* 4 (Risk Management Solutions, Inc. 2006).

along Lake Pontchartrain and the western wall of the 17th Street Canal. Flooding engulfed thirty square miles of Jefferson County and nine square miles of Orleans Parish.¹¹⁰ Hurricane Betsy in 1965 was very damaging to the city. The eastern part of the city was flooded when the Industrial Canal's embankments failed. The storm surge was twelve feet above sea level.¹¹¹ The 17th Street and Industrial Canals also failed during Hurricane Katrina.

The Corps has rebuilt the levee system protecting the greater New Orleans area, but design limits will only protect to a 100-year storm hurricane.¹¹² Katrina started as a Category 5 hurricane and downsized to a Category 3 when it struck New Orleans. Thus, a high probability exists that New Orleans will again fall victim to a major hurricane despite the rebuilt levees.

Both Hurricanes Katrina and Rita were Category 5 hurricanes during their life. The Great Miami Hurricane of 1926 was a Category 4 when it struck downtown Miami. Similarly, Hurricane Hugo was also a category 4 when it hit Charleston. Camille was a Category 5 when it reached the Mississippi Coast on August 17, 1969.

The Mississippi remains untamable by humans.

C. *Southern California: An Environment of Extreme Natural Hazards*

California is known for its seismic risks, but it is also subject to recurring periods of extreme weather, ranging from drought to flooding.¹¹³ A normal cycle is heavy rains, followed by

110. *Id.*

111. *Id.* at 5.

112. See Mark Schleifstein, *New Orleans Area's Upgraded Levees Not Enough for Next 'Katrina,' Engineers Say*, THE TIMES-PICAYUNE (August 18, 2015, 1:18 PM), http://www.nola.com/futureofneworleans/2015/08/new_levees_inadequate_for_next.html. A 100 year flood event is that on average a flood of this magnitude will occur once in 100 years. Since it is an average, the 100 year event could occur more than once in a century or skip a century.

113. See B. LYNN INGRAM & FRANCES MALAMUD-ROAM, *Foreword to THE WEST WITHOUT WATER: WHAT VAST FLOODS, DROUGHTS, AND OTHER CLIMATIC CLUES TELL US ABOUT TOMORROW* at xiii–xiv (2013) (ebook). I remember growing up in San Francisco periodically hearing of recurrent flooding in Guerneville on the Russian River in Sonoma County and Topanga Canyon near Malibu. Documented flooding in Guerneville occurred in 1940, 1943, 1955, 1958, 1963, 1964, 1966, 1969, 1970, 1974, 1978, 1983, 1986, 1995 (twice), 1997, and 2006. See *Current River Information*,

flooding, and then drought and wildfires.¹¹⁴ Few are aware of the history of major flooding in Southern California. The Santa Ana River is only ninety-six miles long, but it is the longest river in Southern California.¹¹⁵ It drains a watershed of 2,650 square miles in Los Angeles County, Riverside County, San Bernardino County, and Orange County from whence it flows into the Pacific Ocean. It was also labeled by the Army Corps of Engineers as the greatest flood hazard west of the Mississippi after the Flood of 1938.¹¹⁶

The March 3, 1938 Flood followed days of heavy rain. Sixty-eight thousand acres were flooded in the county with much of Anaheim and the city of Orange under four feet of water. Even more destructive was the peak flow of an earlier flood in 1862, which was measured at 320,000 cfs.¹¹⁷

The state of California earlier suffered a mammoth flooding in 1861–1862, when a series of storms struck the West Coast. Sixty-six inches of rain fell in Los Angeles.¹¹⁸ Thirty-five inches fell from December 24, 1861 to January 23, 1862 alone.¹¹⁹ Much of Orange County was submerged. The Santa Ana River by Anaheim overflowed four miles out of its banks, four miles

RUSSIAN RIVER HISTORICAL SOCIETY,
http://www.russianriverhistory.org/about/river_info.html (last visited May 29, 2017).
 Topanga Canyon experienced major flooding in 1938, 1969, 1978, 1980, and 1983.
 DIVISION OF ENVIRONMENTAL PLANNING, TOPANGA ENVIRONMENTAL CORRIDOR STUDY
 19, <http://rcdscmm.org/sites/default/files/userfiles/file/Topanga-Corridor-Study-Caltrans.pdf>.

114. The rains come, promoting new growth of vegetation, but also causing flooding, erosion, and landslides. The rains cease, and years of drought set in. The lush vegetation turns into dry vegetation. Something causes a wildfire, which spreads quickly through the dry tinder box, often aided by winds. The fires leave the land bare, facilitating heavy flooding and erosion when the rains return.

115. Nathan Masters, *The Santa Ana River: How It Shaped Orange County*, KCETLINK (Nov. 12, 2012), <https://www.kcet.org/shows/lost-la/the-santa-ana-river-how-it-shaped-orange-county>.

116. Scott Gold, *1938 Flood: A Watershed for the County: Disaster Prompted \$1.3 Billion Effort to Tame Santa Ana River, Protect Basin*, L.A. TIMES (Oct. 3, 1999), <http://articles.latimes.com/1999/oct/03/local/me-18228>.

117. Nita Hiltner, *Santa Ana River Was West's Greatest Flood Hazard*, PRESS ENTERPRISE, <http://www.pe.com/articles/flood-616015-river-santa.html>. Cubic feet per second (cfs) is a standard measurement of water flow, measured as one cubic foot of water per second.

118. B. Lynn Ingram, *California Megaflood: Lessons From a Forgotten Catastrophe*, SCIENTIFIC AMERICAN (Jan. 1, 2013), <https://www.scientificamerican.com/article/atmospheric-rivers-california-megaflood-lessons-from-forgotten-catastrophe/>.

119. Ingram, *supra* note 113 at 28.

to the side of the river, and lasted four weeks.¹²⁰ The Central Valley was a lake up to thirty feet deep in water.¹²¹ Sacramento was submerged under ten feet of water.¹²² Northern Mexico, Oregon, Washington, British Columbia, Arizona, Nevada, and Utah were also subject to severe flooding.¹²³

A series of dams and channelization have controlled the Santa Ana's streamflow, as they have on the neighboring Los Angeles and San Gabriel Rivers. Otherwise much of the Los Angeles Plain would be periodically uninhabitable. The Prado Dam, built in 1941, and the Seven Oaks Dam, constructed in 1999, coupled with cement channelization of portions of the Santa Ana riverbed have contained the river in recent years, but both dams have design limits. For example, the Seven Oaks Dam is designed for a 350-year flood.¹²⁴ The 1862 Flood was viewed as a 1,000-year flood.¹²⁵

California remains at risk for mega-storms in the form of "atmospheric rivers", unleashing heavy flooding on a 200-year basis. The dams, levees, and channels will not control or contain the precipitation.¹²⁶

The eight counties south of the Tehachapi Mountains are an example of humans tempering, but not controlling, nature. The Los Angeles basin is ringed by the Pacific Ocean and a chain of mountains, most notably the Hollywood Hills, the San Gabriel Mountains, the Santa Ana Mountains, the Verdugos, and the Santa Monica Mountains.¹²⁷ The hills are subject to wildfires, landslides, and flash flooding.

Vicious stream flows emerge from the mountains during heavy rains. The risk remains of flooding, landslides, and avalanches at the foothills of the mountains. A major flood overwhelming the dam system might still strike the Los

120. *Id.*

121. *Id.* at 31.

122. *Id.* at 33.

123. *Id.* at 37–38.

124. Hiltner, *supra* note 117.

125. *Id.*

126. See Dettinger & Ingram, *supra* note 50.

127. The mountains trapping the polluted local air, mostly from automobile exhausts, is the reason for the smog inversions in the Los Angeles basin. For a history of Southern California smog, see CHIP JACOBS & WILLIAM J. KELLY, SMOGTOWN: THE LUNG-BURNING HISTORY IN LOS ANGELES (2008).

Angeles plain. John McPhee in his classic book, *The Control of Nature*,¹²⁸ wrote that the public built “debris basins” in downstream areas to catch the debris, including “rivers of boulders” coming out of the San Gabriel Mountains during heavy rainfalls.¹²⁹

IV. RISK REDUCTION MEASURES

We can temper many of the forces of nature, but can never tame nature. We can, for example, stop most flooding (though not in cases of extreme precipitation). To the extent that we cannot control the forces of nature, we need to prepare in advance to reduce the impacts. Earthquakes, hurricanes, tornadoes, and tsunamis will not be deterred by our acts, but the damage and impact can be reduced through several actions. Humans are not helpless against even extreme acts of nature. The purpose of this article is not to list every risk reduction or mitigation measure, natural hazard by natural hazard. Instead, it lays out a few general principles and problems. For example, even if we cannot stop development in risky areas, the risks can be moderated by effective and enforced building codes, professional standards, and statutes.

Four general categories can reduce the risk to people:

Development Bans or Restrictions

Design Standards

Warning Systems

The Response Effort: Emergency Action Plans

Limitations on these measures are the Fifth Amendment and human nature.

A. *Development Bans or Restrictions*

One solution to minimizing the risks from natural hazards would be to avoid living in areas subject to extreme risks, such as Los Angeles, San Francisco, New Orleans or Seattle. A “natural” disaster may involve forces of nature, but the tragedy may be of human origin in geologically fragile areas with a high population density.¹³⁰ The thesis is that humans create

128. JOHN MCPHEE, *THE CONTROL OF NATURE* 191–97 (1989).

129. *Id.* at 192.

130. See Denis Binder, *The Duty to Disclose Geologic Hazards in Real Estate Transactions*, 1 CHAP. L. REV. 13, 45 (1998).

the risk by moving into the natural hazard. Humans turn the forces of nature into disasters.¹³¹

This thesis was advanced by the famous philosopher Rousseau after the Great Lisbon Earthquake of November 1, 1755. The earthquake, estimated to be an 8.5 on the Richter scale,¹³² was followed by a fire and tsunami.¹³³ Much of the city was destroyed by this horrific trifecta of perils. An estimated 60,000 people perished in the disaster.¹³⁴ Most of the city's churches were destroyed on All Saints Day, giving rise to the claim that the earthquake was an act of God.¹³⁵

131. In this respect, the term "natural disaster" can be viewed as an oxymoron.

132. MARK MOLESKY, *THIS GULF OF FIRE: THE DESTRUCTION OF LISBON OR APOCALYPSE IN THE AGE OF SCIENCE AND REASON* 6–7 (2015). It is estimated to be 8.5–9.1 on the Mw scale (local magnitude scale) rather than the Richter Scale. The earthquake zone covered 5.8 million miles. Tremors were felt not only in Portugal, but also in Sweden, Norway, Germany, Netherlands, Ireland, Italy, Sardinia, Greenland, Cape Verde, the Azores, England, and Venice. *Id.* at 111–15. It was especially damaging in Morocco and Tunisia in North Africa. *Id.* at 18–19. A tsunami hit Lisbon one-half hour after the earthquake. It also struck Spain, Morocco, Northeast Brazil, the West Indies, and Newfoundland. Waves reached Brittany, France, Brest, Cornwall, and Plymouth. *Id.* at 143–44. *See also* EDWARD PAICE, *WRATH OF GOD: THE GREAT LISBON EARTHQUAKE OF 1755* (2008) and NICHOLAS SHADY, *THE LAST DAY: WRATH, RUIN & REASON IN THE GREAT LISBON EARTHQUAKE OF 1755* (2009).

133. History demonstrates that large earthquakes or tsunamis are often followed by great fires. Two examples are the Great Lisbon Earthquake of 1755 and the San Francisco Earthquake and Fire of April 18–21, 1906. The 7.8 magnitude earthquake struck San Francisco on April 18, 1906, destroying many buildings in the central downtown area of the city. The earthquake was followed by four days of fire. Over 500 blocks in were leveled. Over 28,000 buildings were destroyed in the inferno. The estimated fatalities exceeded 3,000 with about 250,000 rendered homeless. *San Francisco Earthquake of 1906*, *ENCYCLOPEDIA BRITANNICA* (June 16, 2017), <https://www.britannica.com/event/San-Francisco-earthquake-of-1906>. The earthquake razed only 2 percent of the buildings with the fires destroying the other 98 percent. *The San Francisco Earthquake of 1906: An Insurance Perspective*, *INS.E. INST.*, <http://www.iii.org/article/san-francisco-earthquake-1906-insurance-perspective> (last visited June 16, 2016).

134. Marc-Andre Gutscher, *What Caused the Great Lisbon Earthquake?*, 35 *SCI.* 5688, 1247 (2004). The earthquake damaged cities in Morocco with substantial loss of life in Algeria and Morocco and the tsunami reached Ireland, Cornwall in England and the Caribbean. *1755 The Great Lisbon Earthquake and Tsunami, Portugal*, *SMS TSUNAMI WARNING*, <http://www.sms-tsunami-warning.com/pages/tsunami-portugal-1755> (last visited May 30, 2017).

135. For a deconstruction of the act of God defense in Tort Law, *see* Denis Binder, *Act of God? Act of Man?: A Reappraisal of the Act of God Defense in Tort Law*, 15 *REV. LITIG.* 1 (1996). The Great Lisbon Earthquake is often viewed as the "First Modern Earthquake" because it led to the first study of seismology and building codes. Professor Villa in his companion piece in this symposium posits a role for the Act of God to continue to play in environmental disasters, Clifford J. Villa, *Is the "Act of God" Dead?*, 7 *WASH. J. ENVTL. LAW AND POL'Y* __ (forthcoming July 2017).

Rousseau wrote to Voltaire “that it was hardly nature who assembled twenty-thousand houses of six or seven stories. If the residents of this large city had been more evenly dispersed and less densely housed, the losses would have been fewer or perhaps none at all.”¹³⁶

The seemingly simple solution would therefore be to live in areas risk free from geological or meteorological risks. This approach is untenable. Three hundred and twenty-four million Americans must live somewhere as do seven billion people globally.¹³⁷ A hazards map of the United States looking at seismic, volcanic, hurricane, tornado, flooding, and wildfire threats will show basically no safe zone.¹³⁸ People often continue to live in geologically and meteorologically unsafe areas because they have no viable alternative.

Most disaster losses are performed on built environments. For example, an earthquake in the barren desert will not cause the same losses in human lives, property damages, and economic losses as a similar seismic event in a large metropolitan area.¹³⁹ So too with hurricanes striking a deserted coast rather

The act of God defense has been refined over the past century to have two elements: 1) an unforeseeable event; and 2) the absence of human fault in causing the damages. Thus, if an act of God coalesces with a human act, then the defense fails. Binder at 17–18. For example, excessive precipitation may be an act of God, but building in floodplains and filling wetlands are acts of humans.

If an event has happened before, then it is foreseeable that it will happen again. A disaster may be the result of an uncontrollable natural cause, but it is not unforeseeable if it occurred before. The test then becomes what should the reasonable person, or expert, do in light of that knowledge. The act of God defense thereby fails.

136. Letter from Jean Jacques Rousseau to Voltaire, (Aug. 18, 1756), CORRESPONDENCE COMPLÈTE DE JEAN JACQUES ROUSSEAU, J.A. Leigh, ed., vol. 4 (Geneva, 1967); translated by R. Sprang. The phrase is written in French, and different translations into English have slightly different wording, but the meaning remains the same.

137. The Census Bureau estimated the United States population on January 1, 2017 to be 324,310,011 and the world's 7,362,350,168. Press Release, U.S. Census Bureau, Census Bureau Projects U.S. and World Populations on New Year's Day (Dec. 28, 2016), <https://www.census.gov/newsroom/press-releases/2016/cb16-tps158.html>. A tragic example of people living in hazardous conditions is Bangladesh where 35–77 million drink arsenic contaminated drinking water. Allen H. Smith et al, *Contamination of Drinking Water in Bangladesh: A Public Health Emergency*, 78 BULLETIN OF THE WORLD HEALTH ORG. 9, 1093 (2000).

138. See *supra* notes 13–32 and accompanying text.

139. An earthquake of 7.0 magnitude knocked an Amtrak train off its tracks with four passengers injured. The epicenter of the earthquake was in the Mojave Desert by the Twentynine Palms Marine Base. The earthquake was felt in Las Vegas and Los Angeles. About 250,000 temporarily lost power, but no major damage ensued. Tom

than a coastal city.¹⁴⁰ The larger the population, the greater the potential disaster.¹⁴¹ Therefore, areas subject to severe natural risks are often densely populated with the risks of nature compounded by the human built environment.

One measure to reduce risk is to ban development in areas subject to extreme natural hazards. That approach, though, may run afoul of the Takings Clause and thus encounters constitutional barriers. The Fifth Amendment Takings Clause¹⁴² can serve as a restraint on public officials seeking to restrict development in perilous areas. Justice Black in his majority opinion in *Armstrong v. United States*¹⁴³ wrote the purpose of the Takings Clause is “designed to bar Government from forcing some people alone to bear public burdens, which in all fairness and justice, should be borne by the public as a whole.”¹⁴⁴ This right is not absolute.

The conundrum arises in that the government can exercise the “police power” to protect the public.¹⁴⁵ The government can thereby engage in reasonable regulations to protect the public. The police power includes “everything essential to the public safety, health, and morals, and to justify the destruction or abatement . . . of whatever may be regarded as a public

Gorman and Mitchell Landsberg, *7.0 Earthquake in Mojave Desert Rocks Southland*, L.A. TIMES (Oct. 17, 1999), <http://articles.latimes.com/print/1999/oct/17/news/mn-23272>.

140. Fourteen of the twenty largest cities in the United States and 670 of the nation's 3,111 counties lie in the coastal zone. THE JOHN H. HEINZ III CENTER FOR SCIENCE, ECONOMICS, AND THE ENVIRONMENT, HUMAN LINKS TO COASTAL DISASTERS 19, 24 (2002).

141. The devastation caused by Hurricane Sandy in New Jersey and New York is an example of a hurricane striking a high populated area with little hurricane protection. The hurricane struck a 600-mile-wide stretch of the East Coast, especially damaging New Jersey and New York, on October 29, 2012 during a full moon. Fourteen feet waves struck Battery Park in Manhattan. Parts of the New York City subway system was flooded. Over 650,000 homes were destroyed or damaged. Eighty Percent of Atlantic City was under water. An eight and a half foot storm surge struck Sandy Hook, New Jersey. Estimated damages exceeded \$50 billion, including \$19 billion in New York City. Kimberly Amadeo, *What Are the Facts About Sandy's Damage and Economic Impact?*, THE BALANCE, <https://www.thebalance.com/hurricane-sandy-facts-3305501>.

142. The Fifth Amendment provides “[N]or shall private property be taken for public use, without just compensation.” U.S. CONST. amend V.

143. 364 U.S. 40 (1960).

144. *Id.* at 49.

145. The classic standard “police power” is in *Lawton v. Steele*, 152 U.S. 133, 137 (1894).

nuisance.”¹⁴⁶ The government can also destroy property under this power.¹⁴⁷

The problem is drawing a line between a reasonable regulation and a taking. A definitive interpretation of the takings issue has defied jurists and commentators. Thus, Justice Brennan acknowledged in *Penn Central Transportation Co. v. City of New York*,¹⁴⁸ “[T]his Court, quite simply, has been unable to develop any ‘set formula’ for determining when ‘justice and fairness’ require that economic injuries caused by public action be compensated by the government, rather than disproportionately concentrated in a few persons.”¹⁴⁹ Unsurprisingly, past attempts to restrict development in floodplains have been unsuccessful, absent acquiring the land.¹⁵⁰

Attempts to restrict development in floodplains and along the coastal zone have met Constitutional resistance under the Takings Clause. The Supreme Court in *Lucas v. South Carolina Coastal Commission*¹⁵¹ struck down a total ban on construction or reconstruction of a destroyed building in a coastal zone conservancy zone. *Dolan v. City of Tigard*¹⁵² invalidated the forced dedication of private property as a public greenway within a floodplain. A total deprivation of use, as in *Lucas*, is highly suspect. Forced entry is also highly suspect, as in *Dolan*, because of the historic property right of an owner to exclude others.¹⁵³

146. *Id.* at 136.

147. *Id.*

148. 438 U.S. 104 (1978).

149. *Id.* at 124.

150. State courts split prior to the enactment of NEPA, which occurred on Earth Day April 17, 1969, on the constitutionality of restricting wetlands and floodplains developments. *See, e.g.,* Iowa Nat'l Res. Council v. Van Zee, 158 N.W.2d 111 (Iowa 1968) (upholding restrictions), Comm'r Nat'l Res. v. S. Volpe & Co., Inc., 206 N.E.2d 666 (Mass. 1965) (same), Hager v. Louisville & Jefferson Cty. Planning & Zoning Comm'n, 261 S.W.2d 619 (Ky. 1953) (denying constitutionality of restrictions), Morris Cty. Land Improvement Co. v. Twp. of Parsippany-Troy Hills, 193 A.2d 232 (N.J. 1963) (denied), Dooley v. Town Plan and Zoning Comm'n, 197 A.2d 770 (Conn. 1964) (same), Hofkin v. Whitmarsh, 42 Pa. D. & C. 2d 417 (1967) (same). Later cases generally went up to the United States Supreme Court under the Takings Clause. *But see* Just v. Marinette County, 201 N.W.2d 761 (Wis. 1972).

151. 505 U.S. 1003 (1992).

152. 512 U.S. 374 (1994).

153. One of the most important sticks in the bundle of sticks is the right to exclude. *Lucas*, 505 U.S. at 1017.

An alternative, though, is for the government to acquire lands, such as those subject to periodic flooding. One way to accomplish that task is through conservation easements.¹⁵⁴

B. Design Limits as a Constraint on Eliminating Natural Risks

Society responds to disasters by enacting safety codes, such as building standards, fire codes, and health and safety requirements. In addition, professional groups promulgate professional standards.¹⁵⁵

These pre-incident building standards, building codes, fire codes, health and safety codes, and professional standards can minimize the impact of extreme hazards. Emergency action and business continuity plans can affect response and recovery. Public officials may be trained and tested in emergency responses.

These measures are standard restrictions in the United States to minimize natural hazards. They can be effective in reducing many risks, but may have limits when it comes to extreme natural hazards.

Both natural objects, such as rivers, and human developments have design limits. If a river exceeds its carrying capacity, then flooding occurs. The effectiveness of any preventative, redundancy, resiliency, or response measure is dependent upon its design limits. For example, a bridge designed to resist a twenty-five-year-flood could wash away in a forty-two to fifty-five year-flood.¹⁵⁶

Every facility and structure has design limits which does not usually, and perhaps cannot, protect against extreme geological or meteorological risks. Structures, such as bridges, canals, channels, dams, highways, skyscrapers, and tunnels,

154. See, e.g., Zachary A. Bray, *Reconciling Development and Natural Beauty: The Promise and Dilemma of Conservation Easements*, 34 HARV. ENVTL. L. REV. 119 (2010).

155. For example, the National Fire Protection Agency published a wide array of professional standards, including emergency responses. See NFPA 1600: Standard on Disaster/Emergency management and Business Continuity Plans, NAT'L. FIRE PROTEC. ASS'N. (2016).

156. See *Wright v. United States*, 568 F.2d 153, 156 (10th Cir. 1997), cert. denied, 439 U.S. 824 (1978). The twenty-five-year flood is one expected to occur once every twenty-five years on average. The forty-two to fifty-five-year flood event would thus be expected to roughly occur twice in a century.

are necessary for civilization to survive and minimize natural risks. All, though, have design limits; they will provide little protection against a force of nature that exceeds those limits.

Design limits are based on many factors, including foreseeable risks, legal requirements, professional codes and standards, costs, cost/benefit and risk/benefit analysis, and available technology. Problems can also exist with improper designs and shoddy construction.

A clear example of design tradeoffs is the levee system. The most severe hurricanes are classified at Category 5. The rebuilt levee system around New Orleans after Hurricane Katrina is only for a 100-year storm hurricane.¹⁵⁷

Cost and utility are important tradeoffs in designs. We intuitively understand that a small, economical car will probably be less safe in an accident than a large SUV, but the tradeoffs include increased fuel economy and affordability. The drive for absolute safety can render the end product uneconomical.

Design limits are, in turn, dependent upon the quality of the design, construction, modifications, maintenance, operations, inspections, and improvements. The Fukushima disaster is an example of an original design meeting the safety standards at the time of construction, but a failure to upgrade as changes in risk awareness and technology improvements arise.

The Tokyo Electric Power Company (TEPCO)'s Fukushima Nuclear Complex of six reactors experienced a catastrophic meltdown on March 22, 2011. Three of the six reactors were down for maintenance when the Great East Japan Earthquake with a magnitude 9.0 struck Japan. The reactors' emergency program performed as planned with the three active reactors automatically shutting down.¹⁵⁸

157. See Schleifstein, *supra* note 112. The classification system for hurricanes and the 100 year flood do not correlate. The Saffir-Simpson Hurricane Wind Scale measures the wind velocity of the storm. A Category 3 storm has winds between 111 mph and 129 mph, a Category 4 has winds between 130 mph to 156 mph, and a Category 5 has winds over 157 mph., *Categorizing Hurricanes: The Saffir-Simpson Scale*, ACCUWEATHER (June 16, 2017), <http://www.accuweather.com/en/weather-glossary/what-is-the-saffirsimpson-hurr/13895047>. A 100 year storm is a flood that has a 1 percent chance of occurring in any one year. Andrea Thompson, *What Is a 100-Year Storm*, LIVE SCI., (Sept. 22, 2009), <https://www.livescience.com/5751-100-year-storm.html>. The storm surge of a hurricane, and thus its flood potential, is not necessarily a factor of its wind speed. *Id.*

158. *Fukushima Accident*, WORLD NUCLEAR ASS'N, (Apr. 2017), <http://www.world->

However, a tsunami of thirteen to fifteen meters high struck fifty minutes later. It swept over the complex's ten-meter-high seawall, destroying the emergency generators cooling the six reactors. Both the earthquake and tsunami were of epic proportions.

The fault lay with TEPCO. The nuclear complex met the safety standards at the time they were constructed. TEPCO, however, later received warnings that they were inadequate in light of the foreseeable risks. TEPCO failed to make improvements in light of these warnings.¹⁵⁹ Thus, it was unprepared for a foreseeable event.¹⁶⁰ TEPCO subsequently admitted fault.¹⁶¹

Design limits are also based on the state of the art—what the professionals reasonably believed at the time. Knowledge and technology change over time. Gains in technology are often based upon learning from one's mistakes.

Professor Henry Petroski's book, *To Engineer is Human*,¹⁶² provides a fascinating look at how civil engineering has advanced through the ages upon its mistakes. Katrina is the greatest human caused engineering disaster in American history. A post-Katrina assessment of the disaster concluded that while the storm exceeded design levels, the structures did not perform as designed.¹⁶³

A tradeoff will often exist between safety and utilization. Only eight mobile homes out of roughly 1,300 survived Hurricane Andrew in Homestead, Florida in 1980. The federal government weighed tightening the mobile home wind safety

nuclear.org/information-library/safety-and-security/safety-of-plants/fukushima-accident.aspx.

159. Neither TEPCO nor the government regulators took or required action in light of the revised risks. *Id.*

160. One result of the inaction is that the former president and two vice presidents of TEPCO were indicted on manslaughter charges.

161. TEPCO admitted it had made no safety improvements since 2002 even though it knew they were needed. Their 5.7 meter high seawall was insufficient to restrain the fourteen meter high tsunami. Justin McCurry, *Fukushima Disaster Could Have Been Avoided, Nuclear Plant Operator Admits*, GUARDIAN (Oct. 15, 2012), <https://www.theguardian.com/environment/2012/oct/15/fukushima-disaster-avoided-nuclear-plant>.

162. Henry Petroski, *TO ENGINEER IS HUMAN: THE ROLE OF FAILURE IN SUCCESSFUL DESIGN* (1982). "[T]he history of structural engineering, indeed the history of engineering in general, may be told in its failures as well as in its triumphs." *Id.* at 9.

163. See Marcus, *supra* note 101.

standards.¹⁶⁴ A spokesman for the United States Department of Housing & Urban Development recognized that the issue required: “[t]he classic balancing act [w]e could make these homes completely safe and solid—so much so that they’d be out of reach for lower-income consumers.”¹⁶⁵

The limits appear in attempting to minimize risks, as shown by a tornado that struck Moore, Oklahoma on May 20, 2013. Twenty-four deaths occurred, including seven school children when the tornado struck their elementary school. The school lacked a tornado shelter.¹⁶⁶ Discussions ensued after the tragedy about putting tornado shelters in schools.¹⁶⁷ The problem with many buildings is retrofitting an existing structure. The costs and technological challenges make retrofitting unfeasible in many instances.

However, design criteria are irrelevant if the actual design is flawed or negligence exists in the construction and implementation of the design, operations, or maintenance. For example, the Teton Dam in Idaho failed on June 9, 1976 during its initial filling due to poor design and construction decisions. Eleven deaths were recorded while about 25,000 were left homeless and nearly three-hundred square miles were flooded.¹⁶⁸ A large number of poor engineering decisions occurred, but the problems were as much institutional within the Bureau of Reclamation as engineering: “[a]n internal Bureau of Reclamation study states that ‘past experiences at other dam sites may have given the USBR designers an unwarranted sense of confidence’”¹⁶⁹

Similarly, a study of Hurricane Andrew’s devastating impact on Florida attributed much of the damage to a combination of “inappropriate design, weak building materials, poor

164. Laurie McGinley, *Storm Wages Over Mobile Home Safety*, WALL ST. J., Aug. 23, 1993, at B1.

165. *Id.*

166. Simon Worrall, *Why Wasn’t This Town Prepared When the Big Tornado Hit?*, NAT’L GEOGRAPHIC (July 8, 2015), <http://news.nationalgeographic.com/2015/07/150708-twister-storm-chasers-moore-oklahoma-weather-tornado-alley-ngbooktalk/>.

167. See Ann Zimmerman, *Tornado Alley Weighs Costs of Safe Rooms: More Oklahomans Back School-Safety Mandates After a Powerful Twister Killed Seven Elementary Students Last Spring*, WALL ST. J., Aug. 19, 2013, at A3.

168. See Denis Binder, *Dam Safety: The Critical Imperative*, 14 LAND & WATER L. REV. 342, 351 (1979).

169. *Id.* at 349.

construction techniques, inadequate inspection and other similar failings.”¹⁷⁰

C. *Emergency Action Plans*

Emergency action plans (EAPs) are a widely accepted method today to respond to emergencies. They should be an integral part of the planning process to minimize risk, if not of the initial impact of the force of nature, but the impacts of the impacts of the blow, and to facilitate recovery.¹⁷¹ EAPs need to be site specific, risk based, and user friendly.¹⁷² Users need to be familiar with the plan and subject to periodic training on it.¹⁷³ EAPs also need to be updated, not gathering dust on a shelf.¹⁷⁴

EAPs can only be as effective as their quality and implementation. For example, Louisiana Governor Blanco and New Orleans Mayor Nagin had ample warning of the approach of Hurricane Katrina, yet both dithered before calling for an evacuation.¹⁷⁵ The mayor was reported to have consulted with the city’s attorneys about potential legal liability by the city to the businesses who would lose revenue from an evacuation.¹⁷⁶

Policymakers learn from disasters and the weaknesses of EAPs in responding to them. The failure of the New Orleans EAP also showed multiple problems with evacuation plans. Provisions must exist to evacuate the elderly, infirm, and disabled.¹⁷⁷ Any presumption that they could be evacuated

170. Steven T. Maher, *Emergency Decisionmaking During the State of Florida’s Response to Hurricane Andrew*, 17 NOVA L. REV. 1009, 1011 (1993).

171. For a discussion of emergency action plans, see Denis Binder, *Emergency Action Plans: A Legal and Practical Blueprint: Failing to Plan is Planning to Fail*, 63 U. PITT. L. REV. 791 (2002). See also Ken Lerner, *Governmental Negligence Liability in Disaster Management*, 23 URB. LAW. 333 (1991).

172. See Binder, *supra* note 171, at 808.

173. *Id.* at 804.

174. *Id.*

175. Experts had warned that 48 hours would be needed to evacuate New Orleans. The governor and mayor waited until twenty hours before the hurricane struck to order a mandatory evacuation, Lisa Myers, *How Much Blame Does Gov. Blanco Deserve*, NBC NEWS (Oct. 11, 2005), http://www.nbcnews.com/id/9613133/ns/nbc_nightly_news_with_brian_williams-nbc_news_investigates/t/how-much-blame-does-gov-blanco-deserve/.

176. Bruce Nolan, *Katrina Takes Aim*, NEW ORLEANS TIMES-PICAYUNE, Aug. 28, 2005 at 1.

177. See U.S. GOV’T ACCOUNTABILITY OFFICE, GAO-17-200, FEDERAL DISASTER

with the general population was proven false by Katrina. Another issue that arose was that some people would not leave without their pets. Hence, a recognition now exists that consideration must be given to this reality.¹⁷⁸

Learning lessons from past response efforts will improve future responses, but the reality is that the extreme forces of nature can overwhelm the best designs and EAPs. They can minimize the impact of these forces, but cannot defeat them.

D. Warning Systems

One means to reduce the impacts of extreme natural hazards is the widespread use of warning systems. Timely warning systems allow for informed decision-making on preparedness and deciding whether to evacuate or shelter in place. Mass evacuations on short notice will probably be ineffective as roads become congested and panic sets in.

Warnings about the general geological or meteorological risks will probably be no more effective in discouraging people from inhabiting these areas than cigarette warnings in discouraging smoking.¹⁷⁹ The more significant warnings, therefore, will be those in advance of an impact, such as a reverse 911 alert system.¹⁸⁰ For example, the loci of a tornado touching down may be unknown until it occurs, but communities throughout Tornado Alley will sound their sirens in advance of the tornado. Residents scamper to cover; they do not wait to see where the tornado will touch. So too with evacuation orders prior to a hurricane striking, even though the precise path of the storm is unpredictable.

Absent flash floods or sudden dam breaks, time is usually

ASSISTANCE: FEMA'S PROGRESS IN AIDING INDIVIDUALS WITH DISABILITIES COULD BE FURTHER ENHANCED (2017).

178. The Pets Evacuation and Standards Act of 2006 (PETS) was enacted in response to the lesson from Hurricane Katrina. Pub. L. No. 109-308, 120 Stat. 1725 (codified as passed at 42 U.S.C. § 5196a-d).

179. We are inundated with warning notices, such that we tend to ignore most of them. See David Lazarus, *Warning: People Ignore Warning Labels*, L.A. TIMES (Dec. 6, 2016), <http://www.latimes.com/business/lazarus/la-fi-lazarus-warning-labels-20161206-story.html>.

180. Historically, the traditional tornado warning was the community's sirens. Today, tornado warnings are sent over radio, television, cellular text messages, and the reverse 911 alert system. See *Get to Know the Tornado Warning Systems*, RAINBOW INT'L (Apr. 21, 2016), <https://rainbowintl.com/blog/get-to-know-the-tornado-warning-systems>.

available to warn of imminent flooding. Earthquakes do not provide warnings, but warnings can be issued against ensuing tsunamis.

An estimated 230,000–280,000 persons died in the tsunami that followed the Sumatra-Andaman Earthquake of December 26, 2004. Waves up to fifty-seven feet struck twelve countries.¹⁸¹ The victims had no warnings.¹⁸² Conversely, the National Oceanic and Atmospheric Administration reported in 2010 that its tsunami warning system had a 100 percent effective rate for its area of responsibility since the 2005 fiscal year.¹⁸³

V. THE HUMAN FACTOR

No human activity is risk free. People usually make the right decision, rise to the occasion, and often achieve greatness. We do not usually hear of the persons whose decisions averted a “natural” disaster. Conversely, humans also have a seemingly infinite way of being fallible. The reality is that many “natural” disasters will include a human component of fault.

People are fallible. We all have character defects. Arrogance, vacillating, under meds, the not invented here syndrome, avariciousness, judgment calls, indecisiveness, and fear of making a wrong decision, characterize poor decisions. History is full of incidents of poor leadership in crises.¹⁸⁴ Human risks

181. Alan Taylor, *Ten Years Since the 2004 Indian Ocean Tsunami*, THE ATLANTIC (Dec. 26, 2014), <https://www.theatlantic.com/photo/2014/12/ten-years-since-the-2004-indian-ocean-tsunami/100878/>.

182. The Indian Ocean lacked a tsunami warning system at that time. Andrew C. Revkin, *With No Alert System, Indian Ocean Nations Were Vulnerable*, N.Y. TIMES (Dec. 27, 2004), <http://www.nytimes.com/2004/12/27/science/with-no-alert-system-indian-ocean-nations-were-vulnerable.html>.

183. United States General Accounting Office, Report to Congressional Committees, U.S. Tsunami Preparedness: NOAA Has Expanded Its Tsunami Programs, but Improved Planning Could Enhance Effectiveness 20 (GAO-10-10, April 2010).

184. A classic example is the Great London Fire of 1666, which consumed two-thirds of the city, killed six, and left 200,000 homeless. Will & Ariel Durant, *THE STORY OF CIVILIZATION: PART VIII: THE AGE OF LOUIS XIV* 262–63 (1963). History recorded “a memorable instance of folly” when the Lord Mayor of London refused to either order or permit the destruction of forty homes to create a firebreak, or even to remove the furnishings and belongings of Lawyers of the Temple for fear of liability. See *Respublica v. Sparhawk*, 1 U.S. 357, 362 (1788).

also sadly include corruption,¹⁸⁵ derelictions of duty, and corner cutting.

Another human reality is that people do not heed warnings or are even indifferent to the risks. A classic example was eighty-three-year-old Harry Randall Truman who owned a lodge at Spirit Lake for over fifty years near Mount St. Helens. He was warned about the risks of the eruption but refused to evacuate.¹⁸⁶ He said “I’m going to stay right here because, I’ll tell you why, my home and my (expletive deleted) life’s here . . . My wife and I, we both vowed years and years ago that we’ll never leave Spirit Lake. We loved it. It’s part of me, and I’m part of that (expletive deleted) mountain.”¹⁸⁷

Geologic and meteorological quiescence leads to complacency and overconfidence. The attitude is that since nothing has happened, it must be safe. Memories are also short. Measures to reduce risk are part of infrastructure improvements, which involve budgetary constraints. In terms of public budget shortages, infrastructure suffers on two overlapping realities. First, “if it ain’t broke, don’t fix it.” Second, the squeaky wheel of infrastructure—the general belief is that because nothing has gone wrong, it is safe. When the dam bursts, then society pours much more into the infrastructure, much more than preventative maintenance.¹⁸⁸ The result is a ticking time bomb

185. For example, four state assembly speakers (Alabama, New York, Rhode Island, and South Carolina) were indicted for corruption in 2014. Alan Greenblatt, *Politics: 5 Reasons State House Speakers May Be Prone to Corruption*, GOVERNING (Jan. 26, 2015), <http://www.governing.com/topics/politics/gov-speakers-indicted-new-york-rhode-island-south-carolina-alabama.html>. California indicted three state senators for corruption in 2014. Norimitsu Onishi, *California Democrats Await Fallout After 3 Are Caught Up in Scandals*, N.Y. TIMES (Apr. 3, 2014), <https://nyti.ms/1IEHM3E>.

186. Lori Grisham, *“I’m Going to Stay Right Here.” Lives Lost in Mount St. Helens Eruption*, USA TODAY (May 19, 2015), <http://www.usatoday.com/story/news/nation-now/2015/05/17/mont-sr-helens-people-states/27311467/>.

187. *Id.*

188. A clear example is the failure of the spillway and emergency spillway at the 50-year-old, 770 feet Oroville Dam this past winter. Due to low precipitation rates, the Oroville dam does not usually have to open its spillway, much less its emergency spillway. The 2016 winter in California was different. The dam was filling up fast and the spillway was opened. The spillway started cracking up and the emergency spillway turned out to be nothing more than a hill. Studies showed problems in the design of the dam, its construction, and maintenance. In essence, cracks in the spillway were merely patched over the years. See R. G. Bea, *Preliminary Root Causes of the Oroville Dam Gated Spillway*, U.C. BERKLEY CTR. FOR CATASTROPHIC RISK MGMT, (Apr. 17, 2017), <https://www.documentcloud.org/documents/3673031-OrovilleSpillway-RootCauseAnalysis.html>. The low bid to repair the spillway came in at \$275.4 million.

of deferred maintenance.

Others are willing to accept general levels of risk. One Oakland resident living on the Hayward Fault stated: “[l]iving here is a considered risk . . . [b]ut I love this area, and I’d rather live to be 50 in the Bay Area than 100 in Kansas.”¹⁸⁹ The desire to commune with nature, live with nature, exalt in its beauty and views, and to respond to the siren calls of natural beauty, is irresistible to many. To escape from the crowded land and live by the sea¹⁹⁰ is an aspiration of many.

We also deal with conscious denial of the risk—“It won’t happen to me.” One commentator wrote of the hurricane risk on the East Coast:

Theirs is the familiar beach barrier tale of hope against hope, trust that shoreline engineering can fool Mother Nature, reliance on the great faucet of Government disaster aid and cheap storm insurance and ultimately, denial of the obvious—that is, that all up and down the Atlantic Coast, the sea, aided by storms and hurricanes, is slowly but inexorably rolling up and over beaches.¹⁹¹

People may often be unaware of the risk. They may not realize, for example, that they are at risk of a flood because an upstream dam provides a delusion of safety.

The desire often exists to rebuild in the same place in the same way. A team of engineers recommended stricter building codes after Hurricane Iwa struck Kauai in 1982. Their intent was to keep roofs from blowing off structures in future hurricanes.¹⁹² The Kauai County Council waived building permits for “emergency repairs.”¹⁹³ Permittees for the following year were allowed to retroactively obtain permits. “Hurricane connectors,” which attach the rafters to the wall frames, were

See also Dave Kasler, *Bids for Oroville Dam Repairs Top State Estimates: \$275.4 Million the Lowest*, SACRAMENTO BEE (Apr. 15, 2017), <http://www.sacbee.com/news/state/california/water-and-drought/article144848399.html>.

189. *With Fault Like Kobe, Fears Rise in Oakland*, N.Y. TIMES, Jan. 23, 1995, at A11.

190. I had a poster once that showed a person looking out over the ocean. The caption was “I fled from the land and arrived at last by the infinite sea.” I recognized the scene as being at Ocean Beach in San Francisco.

191. B. Drummond Ayres, Jr., *Sea Threatens Costly Building, Reviving a Debate*, N.Y. TIMES, Dec. 24, 1997, at A7.

192. *Hawaii Betrayed by its Leniency*, N. Y. TIMES, Sept. 21, 1992 at A10.

193. *Id.*

not required for another three years.¹⁹⁴ Hurricane Iniki came in 1992 to Kauai with devastating results.¹⁹⁵

Regardless of zoning, land use plans, or planning boards, political pressures exist to develop and build in geologically fragile areas, such as floodplains or slippery slopes. The development of the Big Rock Mesa in Malibu, California, is a prime example of this costly reality.¹⁹⁶ County engineers recognized the instability of the slopes in the 1960s. The hills and slopes of Malibu, with their majestic views of the ocean and the exclusivity of the community, send out a siren call to the affluent.¹⁹⁷

Staff unsuccessfully tried to forestall development pending installation of sewers for waste water development. Political pressures overcame their opposition. Building permits were issued and homes built. The use of septic tanks¹⁹⁸ and a rise in the water table resulted in the foreseeable destabilization of the slopes. The 1983 Big Rock Mesa landslide damaged or destroyed 250 homes. Los Angeles County entered into a \$96.8 million settlement in 1986.¹⁹⁹

VI. CONCLUSION

Sir Francis Bacon wrote, “[n]ature to be commanded must be obeyed”²⁰⁰ People often act in ignorance of this maxim. Humans often fail to heed the lessons from nature.

The march of civilization and the American people has

194. *Id.*

195. *Id.*

196. Malibu has long been known for its slippery slopes. See *Sprecher v. Adamson*, 636 P. 2d 1121 (Cal. 1981). As one commentator wrote: “Malibu, where the slide meets the tide.” Rob Risley, *Landslide Peril and Homeowners’ Insurance in California*, 40 UCLA L. REV. 1145, 1145 (1993).

197. *Id.*

198. Malibu residents long opposed installation of sewers, preferring to rely on septic tanks, and are now installing sewer systems and a wastewater treatment plant. Martha Groves, *Malibu Approves Sewage Treatment Plant*, L.A. TIMES (Jan. 13, 2015), <http://www.latimes.com/local/westside/la-me-0114-malibu-sewer-20150114-story.html>; Martha Groves, *Septic Tanks on Their Way Out in Malibu*, L.A. TIMES (Nov. 6, 2009), <http://articles.latimes.com/2009/nov/06/local/me-malibu-septic6>.

199. Kenneth J. Garcia, *\$97-Million Settlement Over Malibu Landslide: Agreement Requires County, Caltrans, Insurers to Pay Homeowners for Big Rock Mesa Damage*, L.A. TIMES (Jan. 4, 1989), http://articles.latimes.com/1989-01-04/news/mn-124_1_big-rock-mesa.

200. FRANCIS DRAKE, *THE NEW ORGANON, THE FIRST BOOK* (1857).

proven the human race is capable of prodigious feats. It can feed the world's population. It can mine the earth's natural resources in hot humid climates or bitterly freezing, sub-zero weather. It can level mountains, bridge chasms, and make swamps habitable through drainage, filling, and air conditioning.

But humans cannot tame the basic primeval forces of nature—the uncontrollable, extreme natural hazards. These natural risks defy control by humans. The time has come to recognize extreme natural hazards as uncontrollable events that can defy design limits and emergency planning because of their speed and ferocity.

Americans spent 360 years reengineering nature to fit their needs. Earth Day on April 17, 1969 and the enactment of National Environmental Policy Act of 1969 marked the end of the period of resource exploitation and the redesign of nature. Scores of environmental protection statutes followed at the federal, state, and local level. The quality of life became as critical as the quantity of life. The paradigm shifted from resource exploitation to resource conservation. Minimum stream flows were imposed on rivers to protect fish and habitat. The Age of the Big Dam was over.²⁰¹

Yet, natural hazards persist in spite of the engineering of America. Indeed, much of America is dependent on a century of pre-Earth Day infrastructure. We have to accept, and do accept, a degree of risk in our habitations. It is impossible in as vast and diverse society as the United States to protect against all threats everywhere in the country. Structures fail. Systems malfunction. Humans err.

Let us understand that we can temper many of the forces of nature, but can never tame nature. Engineers have done a remarkable record of containing most, but not all, natural risks. Uncontrollable risks defy their best efforts. We can, for example, stop most flooding, but not cases of extreme precipitation when flood waters reach the flood levels of a river.

To the extent that we cannot control the forces of nature, we

201. See Professor Zygmunt Plater's graphic discussion of the Tellico Dam saga, which marked the end of the Big Dam Era. ZYGMUNT J. B. PLATER, *THE SNAIL DARTER AND THE DAM: HOW PORK-BARREL POLITICS ENDANGERED A LITTLE FISH AND KILLED A RIVER* 342–52 (2013).

need to prepare in advance to reduce the impacts. Earthquakes, hurricanes, tornadoes, and tsunamis will not be deterred by our acts, but the damages and impact can be reduced through a number of actions. Humans are not helpless against even extreme acts of nature.

The time has come to recognize these uncontrollable, extreme forces of nature as phenomena unto themselves.